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Green Synthesis and Characterization of Carbon Nanotubes

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ABSTRACT

Carbon nanotubes (CNT) are cylindrical carbon molecules belonging to the fullerene family with unique properties that makes them potentially useful in a wide variety of applications. They exhibit extraordinary strength as well as unique mechanical, electrical, optical and thermal properties. The production of CNT using a low cost method remains a challenge. In this paper, CNT was synthesized using green synthesis method and characterized using UV visible absorption spectra, Fourier transform infrared spectroscopy ¬(FTIR), field emission scanning electron microscope (FESEM) and Raman spectroscopy. The characterized results showed good quality CNT was synthesized with fewer impurities.

KEYWORDS: *Synthesis, Characterization, Carbon Nanotubes*

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1. INTRODUCTION

Carbon nanotubes, discovered in the 1990s, are graphite sheets with fullerene end caps [1-4]. They come in two types: single-walled (1.4 nm) and multiwall (30-50nm) [5, 6]. SWNTs are stronger and harder due to chemical bonding based on sp2 orbital bond [7].

Nanotechnology has advanced significantly with the development of carbon nanotubes (CNTs) [8,9]. However, despite advancements, low-cost methods for producing CNTs with specific features remain challenging due to insufficient understanding of the growing mechanism, the need for an inorganic catalyst, and potential risks associated with nanotubes at manufacturing, disposal, and commercialization sites [10, 11].

High temperatures cause metal catalyst particles to bind to carbon nanotube walls, disrupting lattice wave propagation and affecting temperature sensors [12]. Carbon nanotubes (CNTs) have gained interest in research and industry due to their exceptional strength, electrical and thermal conductivity, high surface area to mass ratio, and special optical features [13, 14].

CNTs, with their high electrical, thermal, and mechanical properties, are versatile and lightweight, making them ideal for applications in nano electronics, photovoltaics and biomedicine [15].

Carbon nanotubes (CNTs) have significantly impacted international research and industry since their discovery in 1991[16]. These nanometer-sized fullerene lattices and flat graphene tubes have unique properties such as exceptional strength, high conductive or semiconductor ability, and high mass ratio. They have also made significant investments in technology development and application development [17-19].

2. Structure of Carbon Nanotubes

CNTs are siblings of sp2 hybridized carbon prime isoforms [20], forming a cylindrical tube with

graphite-shaped six-membered carbon rings. Their chirality determines properties, and a concept called "chiral diagram" is used to understand this [21]. Single-walled carbon nanotubes are metallic, semiconducting, and have various band gaps depending on their chiral vector [22].

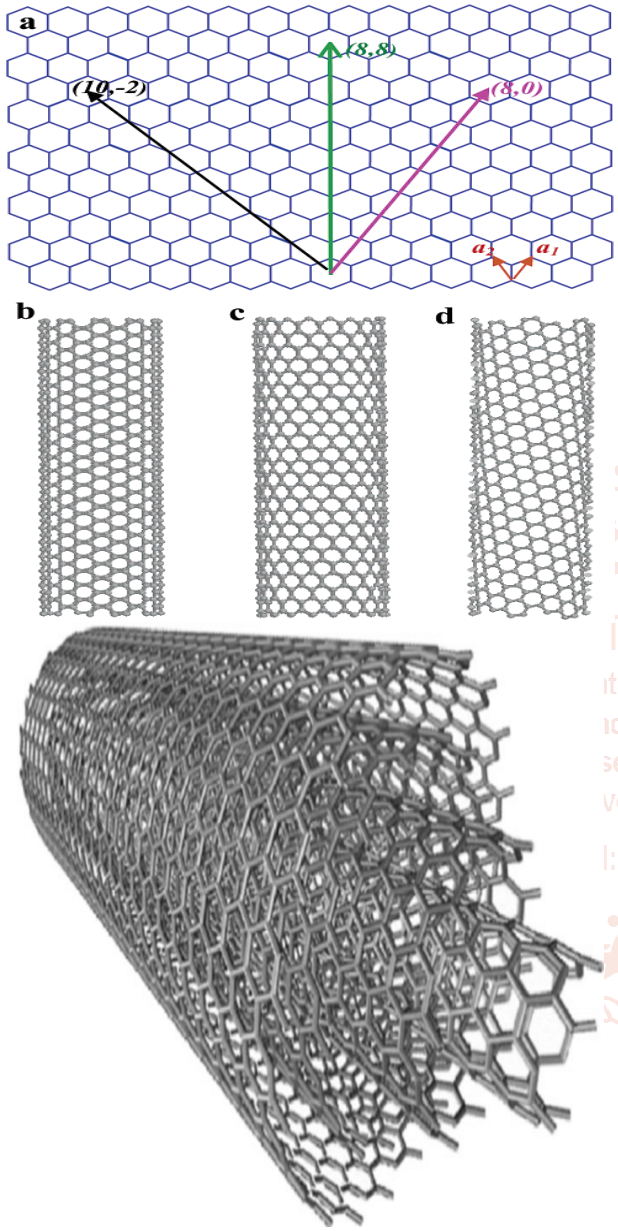

Figure 1: (a) Schematic honeycomb structure of a graphene sheet single walled carbon nanotubes (b) Armchair (c) Zigzag (d) Chiral tube (e) Multi-Walled Carbon Nanotube

3. Properties of Carbon Nanotubes

3.1. Mechanical property

Carbon nanotubes (CNTs) have up to 100 times the tensile strength of steel, with the highest measured value potentially due to process error [23, 24].

3.2. Electrical property

Carbon nanotubes have higher electrical conductivity than copper or gold, with 109 amperes per cubic centimeter [25, 26].

3.3. Optical property

CNTs, with unique absorption and fluorescence spectra, are promising alternatives to transparent ITO in applications like displays, solar panels, and electroluminescent lights due to their transparency in visible and infrared regions [27-29].

3.4. Thermal property

Nanotubes exhibit comparable thermal conductivity to graphite or diamond at room temperature, with the highest thermal conductivity at medium temperature some products [30-33].

4. Synthesis of Carbon Nanotubes

The Wood Melick plant (Melica uniflora) was uprooted, washed, and sun dried until dry. The dried leaves were grounded and sieved to create a powdered material. 1g of the powdered plant was dissolved in 50ml of methanol, stirred, and filtered. Another sample was prepared by dissolving 1g of the powdered plant in 50ml of distilled water and both samples were characterized using Ultraviolet spectroscopy to analyse the absorption and transmission spectra of the sample (figure 2a) in order to determine which of them has greater absorbance.

Carbon nanotubes was synthesized from activated carbon gotten from burnt coconut shells which served as our carbon source, Toluene which served as our extracting solvent and our plant extract which was used as catalyst.

The study involved a reaction of plant extract with activated carbon and toluene using two preparation methods. The first involved adding 1g of activated carbon to 20ml of toluene, mixing for 30 minutes, and heating for 30 minutes. The plant extract was added to the mixture and mixed thoroughly then filtered, leaving a black residue and a yellowish liquid filtrate. The second method involved mixing 0.5ml of plant extract with 1g of activated carbon and 20ml of toluene, heating for 30 minutes, and boiling completely, leaving a black substance. The residues were mixed with methanol and analyzed. The UV Visible Absorption Spectra of CNT were compared after heating with the initial addition of plant extract as shown in figure 2b.

5. Characterization of the Synthesized MWCNTs

The synthesized MWCNTs were characterized using UV, FTIR, FESEM and RAMAN to determine their absorbance, functional group, morphological characteristics and quick screening respectively.

5.1. UV Visible Absorption Spectra

Figure 1 shows the absorbance of the two samples using two different solvents (Methanol and Distilled water). The sample with Methanol (which served as

catalyst) showed a greater absorbance compared to the sample with distilled water.

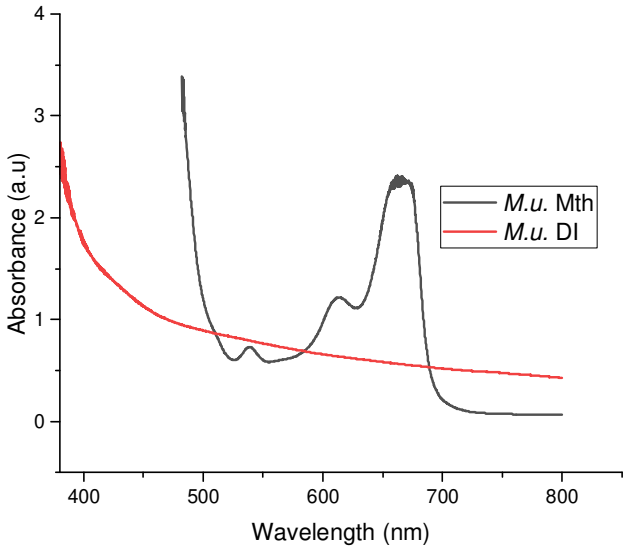

Figure 2a: UV Visible Absorption Spectra of the two samples

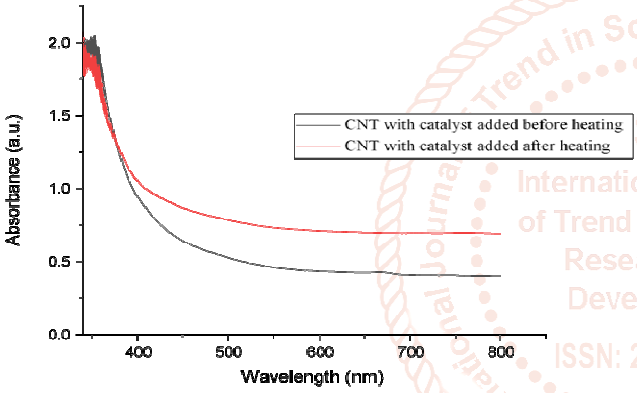

Figure 2b: Comparison of UV Visible Absorption Spectra of CNT with initial addition of catalyst before heating and after heating

Table 1: shows the wavelength, absorbance, and transmittance of the synthesized CNT

Wavelength (nm)	Absorbance (a.u)	Transmittance
400	1.0522	8.87
450	0.8653	13.64
500	0.7849	16.41
550	0.7331	18.49
600	0.7106	19.47
650	0.6994	19.98
700	0.6959	20.14
750	0.6973	20.08
800	0.6931	20.27

5.2. Fourier Transform Infrared Spectroscopy

The FTIR spectra of the synthesized CNTs in the 400-5000 cm^{-1} range show dominant peaks at 460cm^{-1}, 1033cm^{-1}, 1383cm^{-1}, 1624cm^{-1}, 2344cm^{-1}, 2898cm^{-1}, and 3434cm^{-1}. The spectrum reveals vibrational msamuodes corresponding to C-C bonds, C-H bonds, C-O groups, carboxylic C=C acid groups, C≡N cyanide functional groups, C-H bonds in aldehydes and ketones, and stretching vibration of the hydroxyl group (-OH) at 3434cm^{-1}.

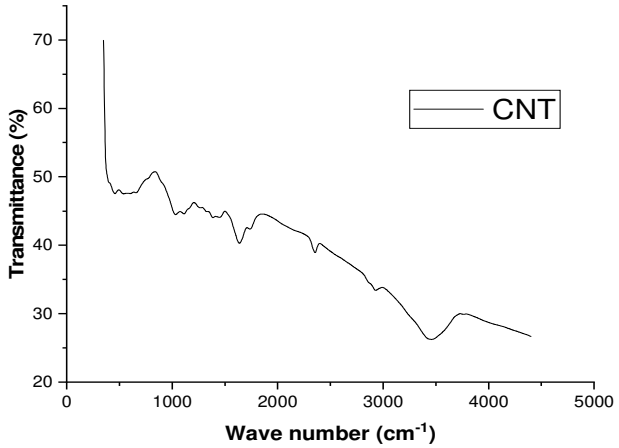

Figure 3: Graphical representation of CNT using FTIR method to show the functional group (carboxylic)

5.3. FESEM images of the synthesized CNT

FESEM was used to study the morphology of the grown CNTs and the corresponding image is shown in figure 4. The FESEM image in figure 4 was taken at magnification of 10.00 KX and fast-tracking voltage of exactly 5.00kV. This image revealed typical morphology of CNTs grown on Wood Melick plant catalyst at a furnace temperature of 900°C. The particle sizes of this CNT sample are irregular wall structure morphology of dimension 1µm. It is obvious, from the result in figure 4 that the grown CNT contain very few impurities (as indicated by red arrow) originating from the catalyst and other material used.

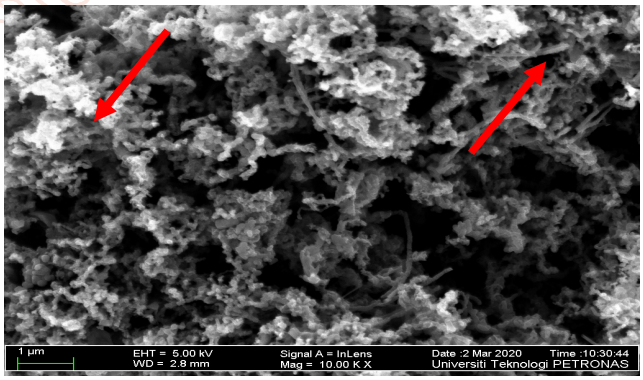

Figure 4: FESEM Image of the CNTs

5.4. RAMAN spectra of the synthesized MWCNT

Raman spectroscopy was used to carry out further analysis of the CNTs as shown in figure 5. The result in Figure showed the Raman spectra of the sample of the CNTs. The results depicted four band with corresponding peak values of 1344.8 cm^{-1}, 1572.95 cm^{-1}, 2690.57 cm^{-1} and 2903.35 cm^{-1} respectively.

The D bands of the sample shown is very high, which is typical of highly dense CNTs and this characteristic can be attributed to the vibrations of carbon atoms bonds in disordered or defective sample.

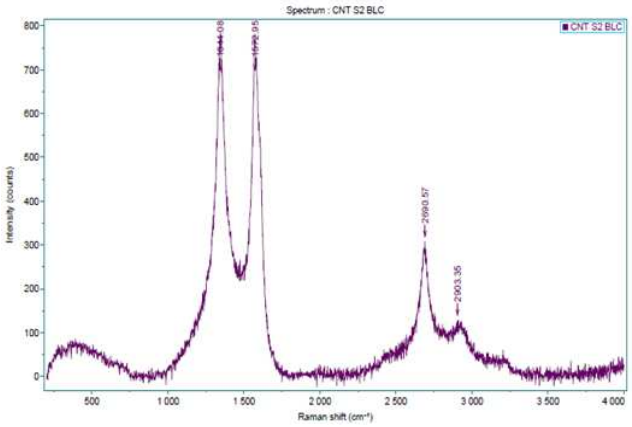

Figure 5: Raman spectrum of the CNTs

6. Conclusion

In this study, the green synthesis method of creating carbon nanotubes (CNTs) was effectively applied. Burnt coconut shells were used as the carbon source, while plant extract was used as the catalyst. Because the methanol sample's peaks are the most evident on the graph, the UV analysis of the plant extracts revealed that it has the larger yield; as a result, the mixture of methanol and wood melick is best suited for use as a catalyst.

The obtained sample was further examined using a field emission scanning electron microscopy and Raman spectroscopy, respectively, to ascertain its morphology and quality. The outcomes demonstrated that the CNT sample's particle sizes have an uneven wall structure morphology with a dimension of 1 µm.

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